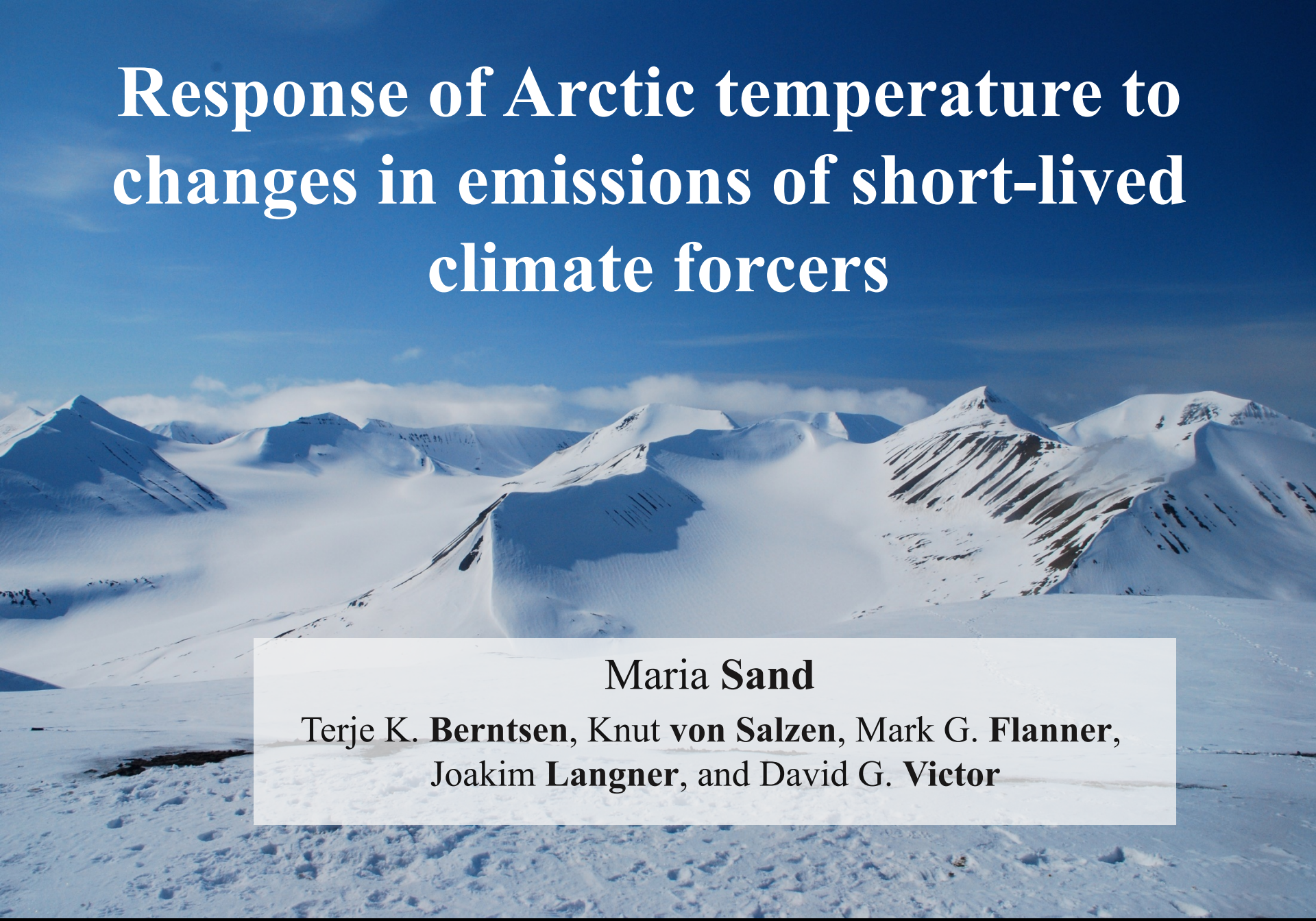
Response of Arctic temperature to changes in emissions of short-lived climate forcers



Maria **Sand**

Terje K. **Berntsen**, Knut **von Salzen**, Mark G. **Flanner**, Joakim **Langner**, and David G. **Victor**

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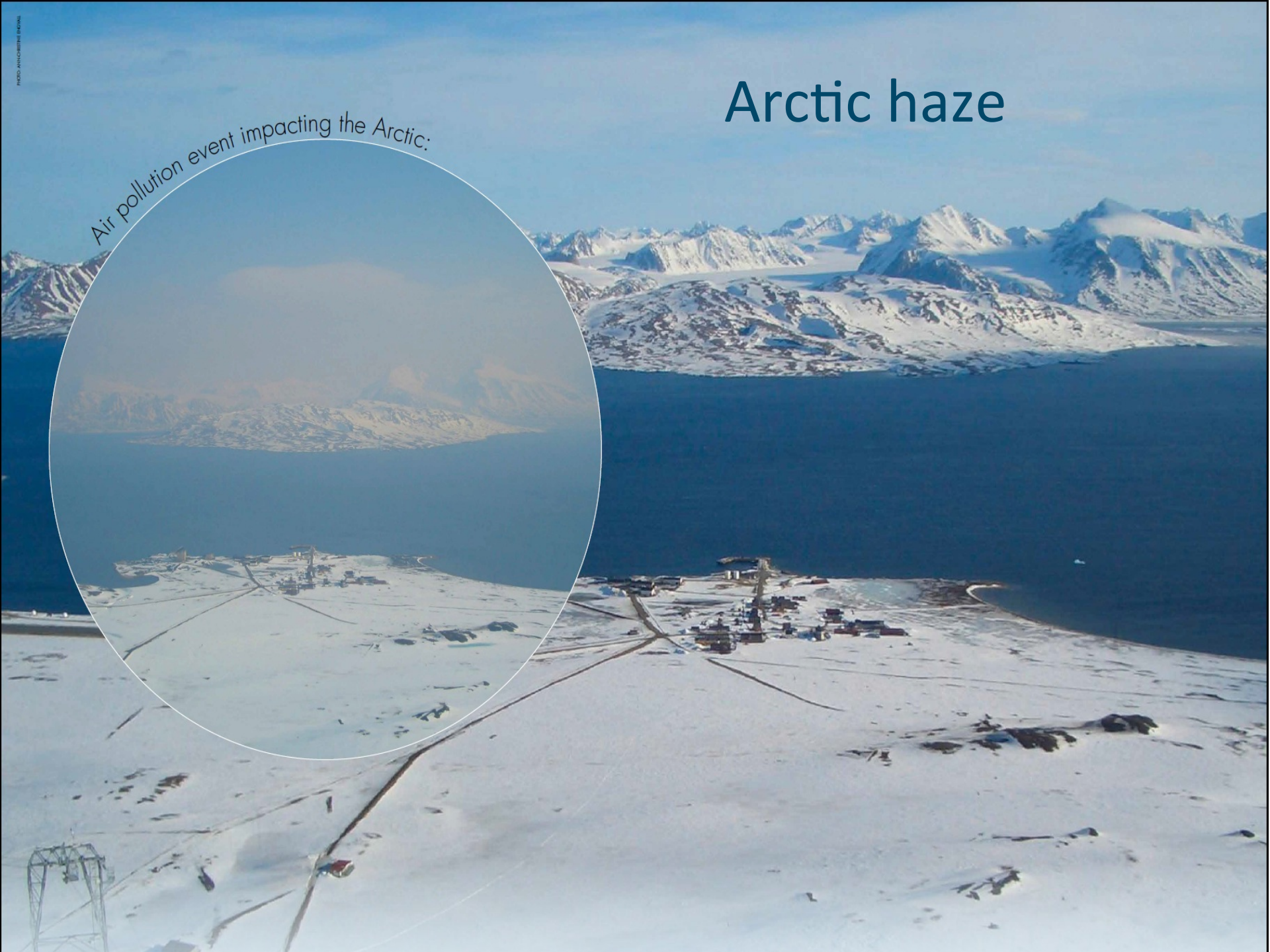
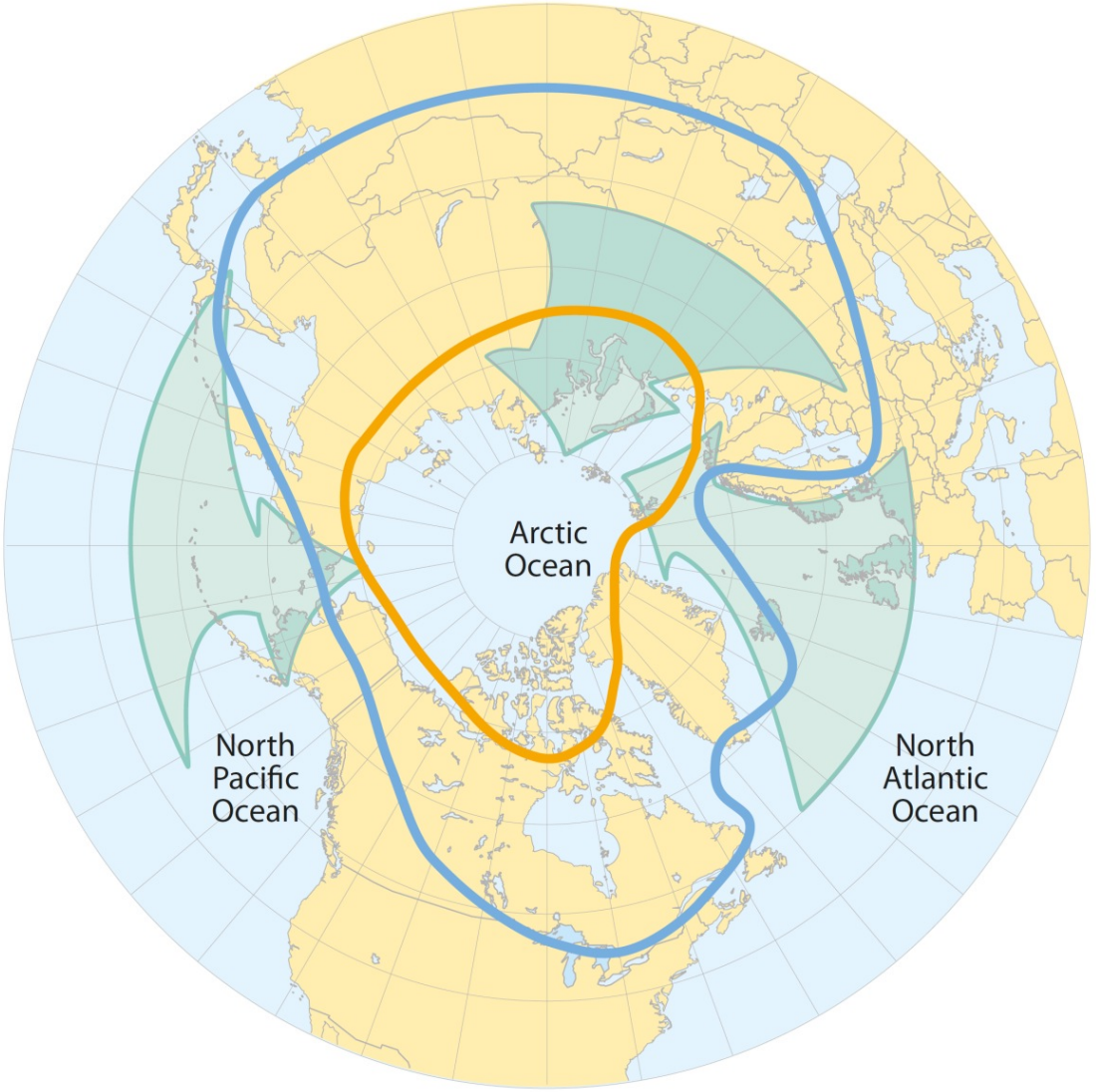
°CICERO Senter for klimaforskning Center for International Climate and Environmental Research - Oslo www.cicero.uio.no

Arctic haze





Arctic Front Winter

Arctic Front Summer

Major south to north air transport routes into the Arctic

CICERO Senter for klimaforskning www.cicero.uio.no
Center for International Climate and Environmental Research - Oslo

What are SLCFs?

Gases and particles that have an atmospheric lifetime of a few days to a decade.

BLACK CARBON

Soot produced from combution sources. Absorbs solar radiation.

CO-EMITTED POLLUTANTS

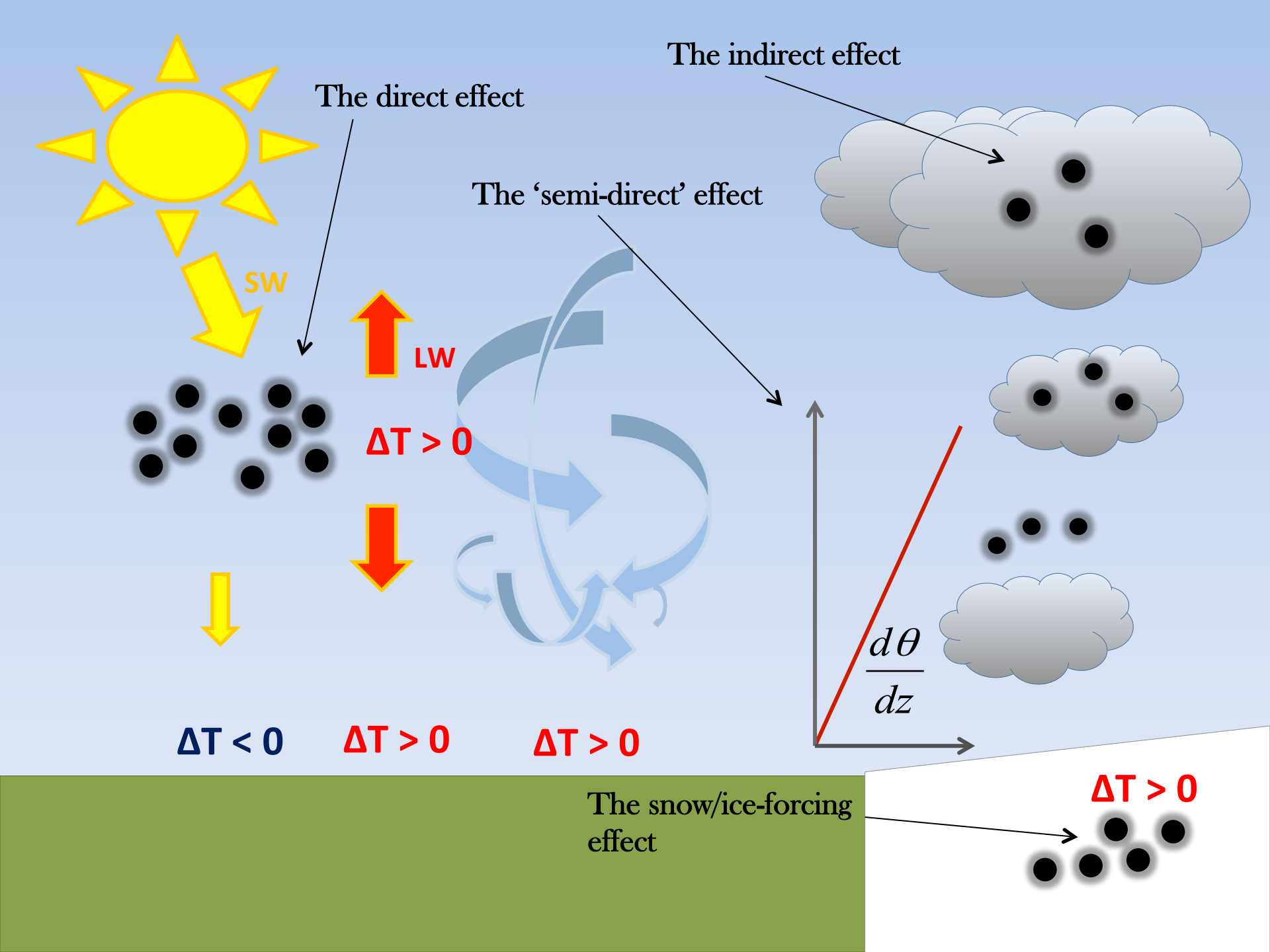
~ Sulfur dioxide, organic carbon componds. Scatter solar radiation.

OZONE

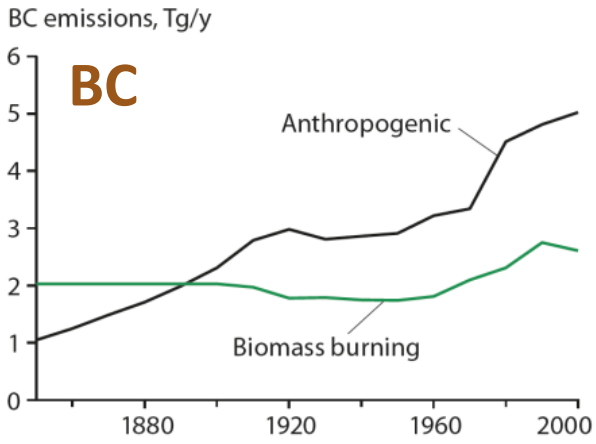
Tropospheric ozone, air pollutant, harmful. Green house gas.

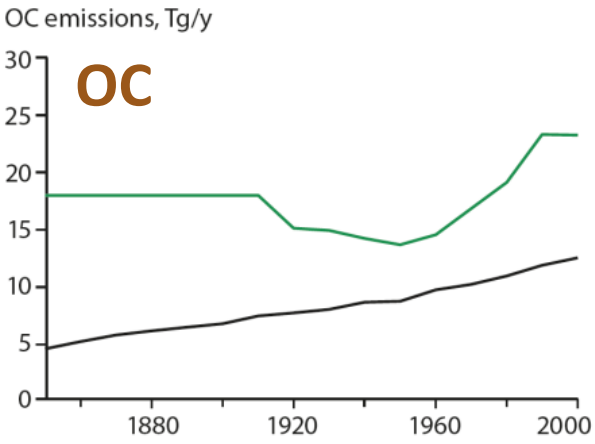
METHANE

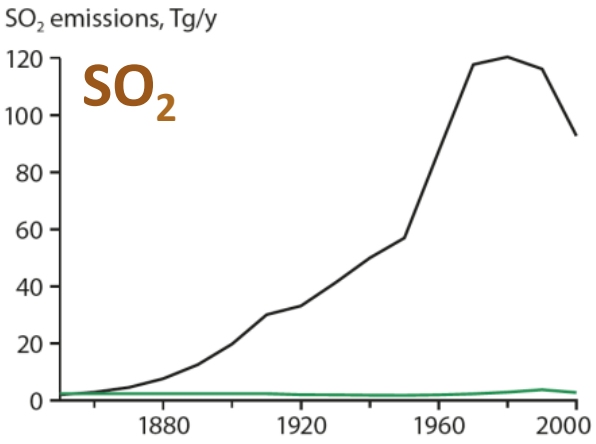
Other report ☺

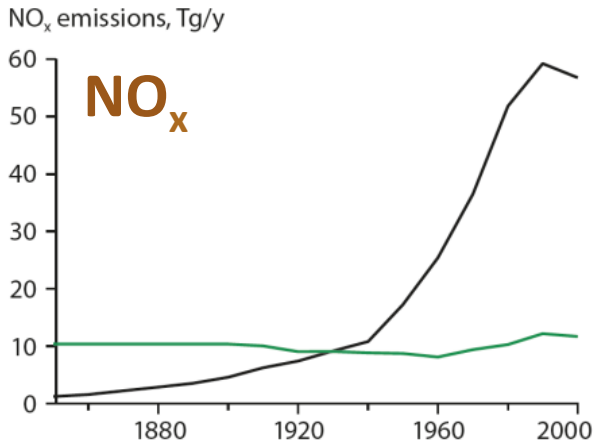

The direct effect
The indirect effect
The 'semi-direct' effect
SW
LW
ΔT > 0
$\frac{d\theta}{dz}$
ΔT < 0
ΔT > 0
ΔT > 0
The snow/ice-forcing effect
ΔT > 0

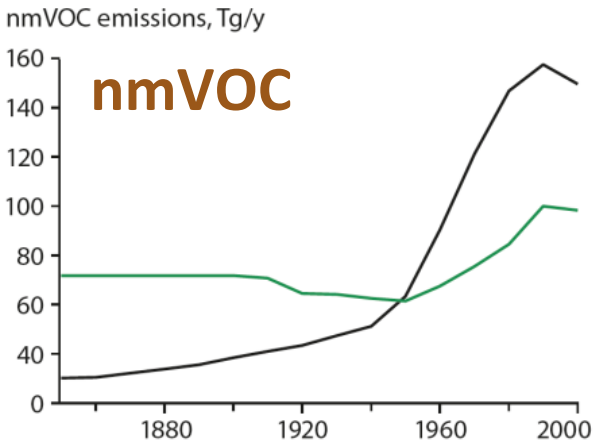
Global trends in SLCFs emissions











Gridded emissions 1850-2000 Lamarque et al. (2010).

AMAP BC&O$_3$ report, 2015

Short-lived Climate Forcers Affecting the Arctic

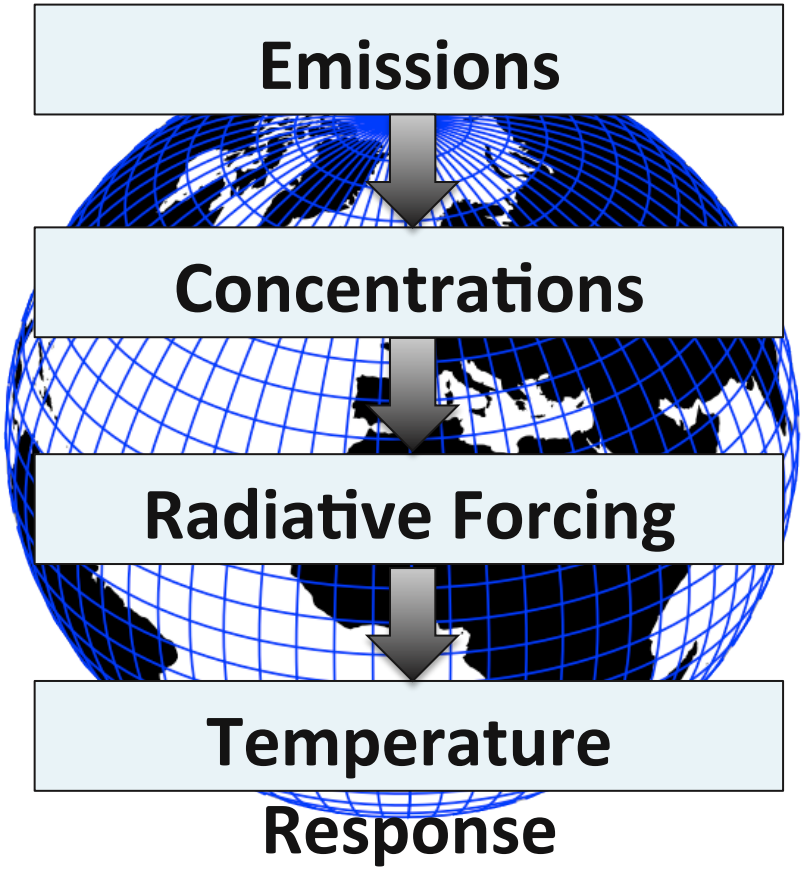
Goal: Assess the impact on Arctic climate of SLCF emissions from different regions and sectors

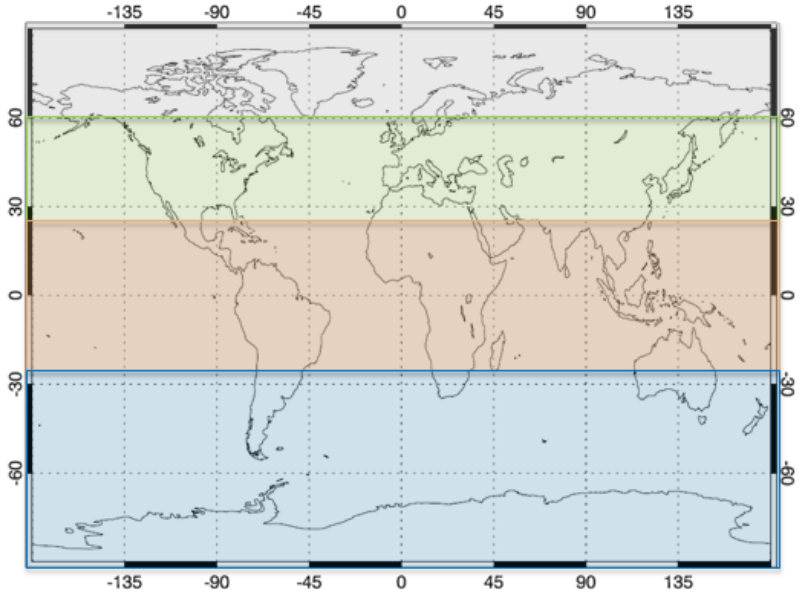
- Challenging task because of small *d*(climate) signal and large uncertainties, especially due to cloud indirect effects

AMAP
Arctic Monitoring and Assessment Programme

Problem: small perturbations, large variability

Estimating the climate response



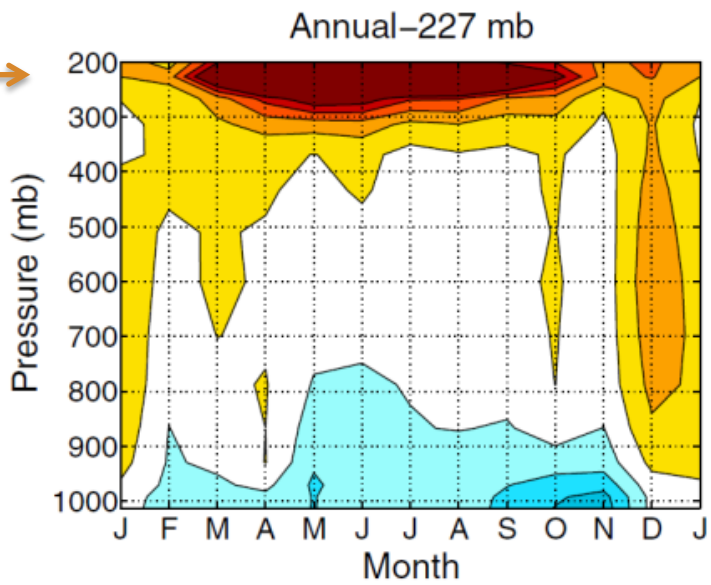


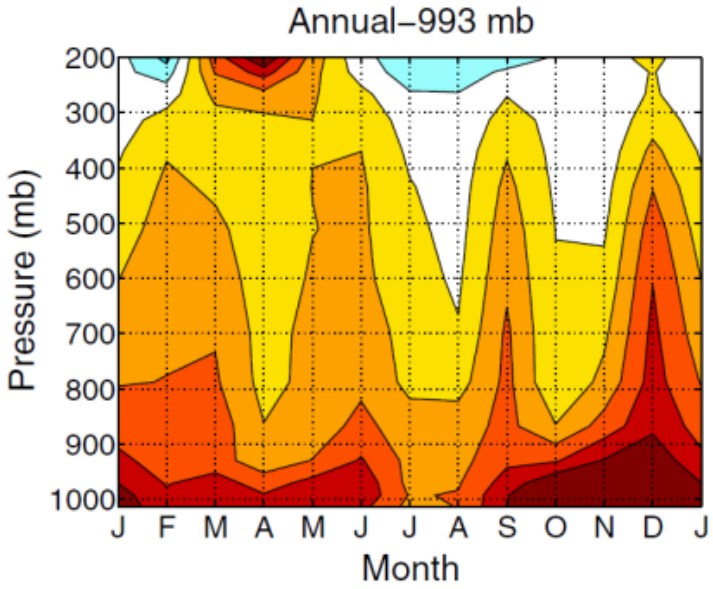
Using **regional temperature sensitivity factors**: allows a rapid evaluation of regional emission reductions (*Shindell and Faluvegi, 2009; Shindell 2012*)

Surface temperature response altitude dependent

Increased **absorption** at **higher altitudes** in the Arctic (positive forcing) could lead to **surface cooling.**

Increased AAOD →





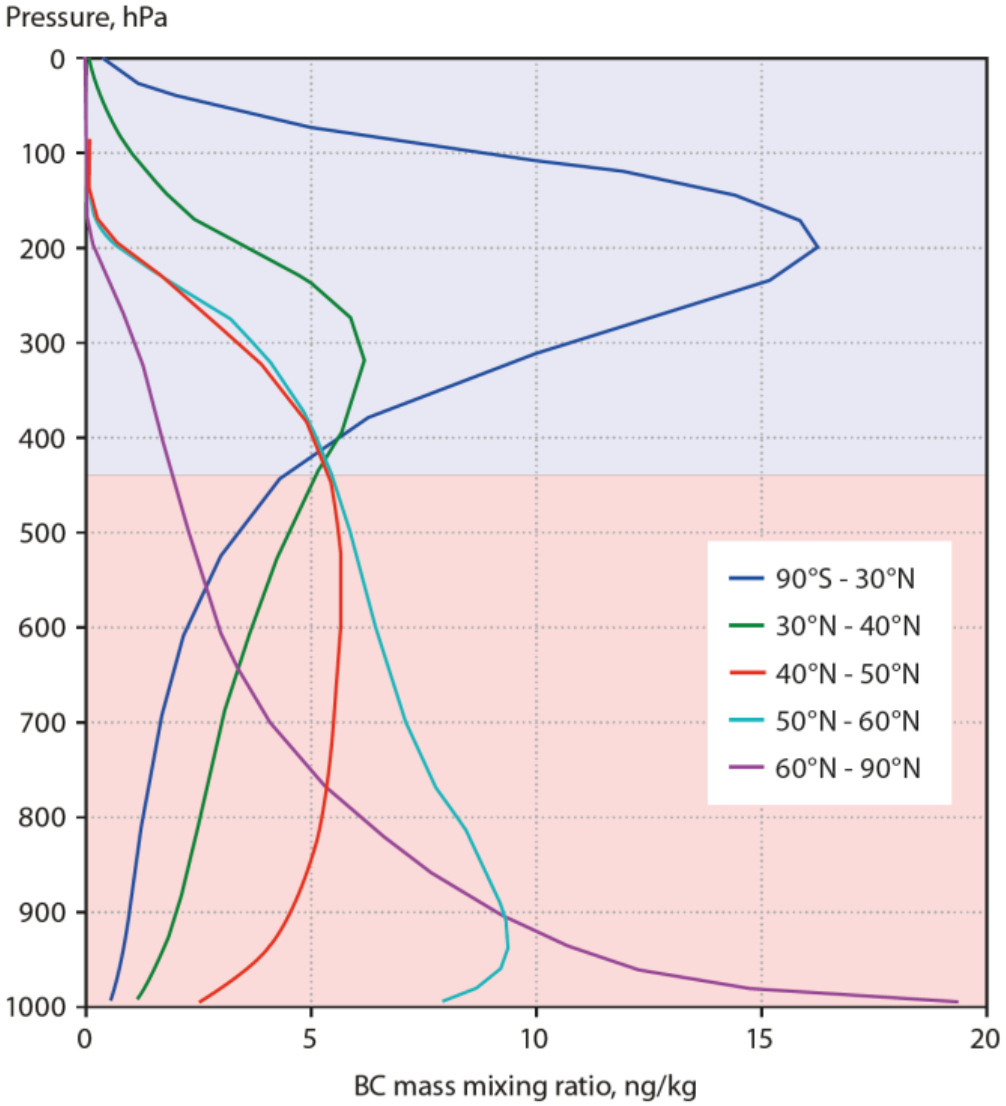
← Increased AAOD

Flanner, JGR,2013

Surface temperature response altitude dependent

Vertical profiles of BC in the Arctic

→ originating from BC emissions occurring within different latitude bands.

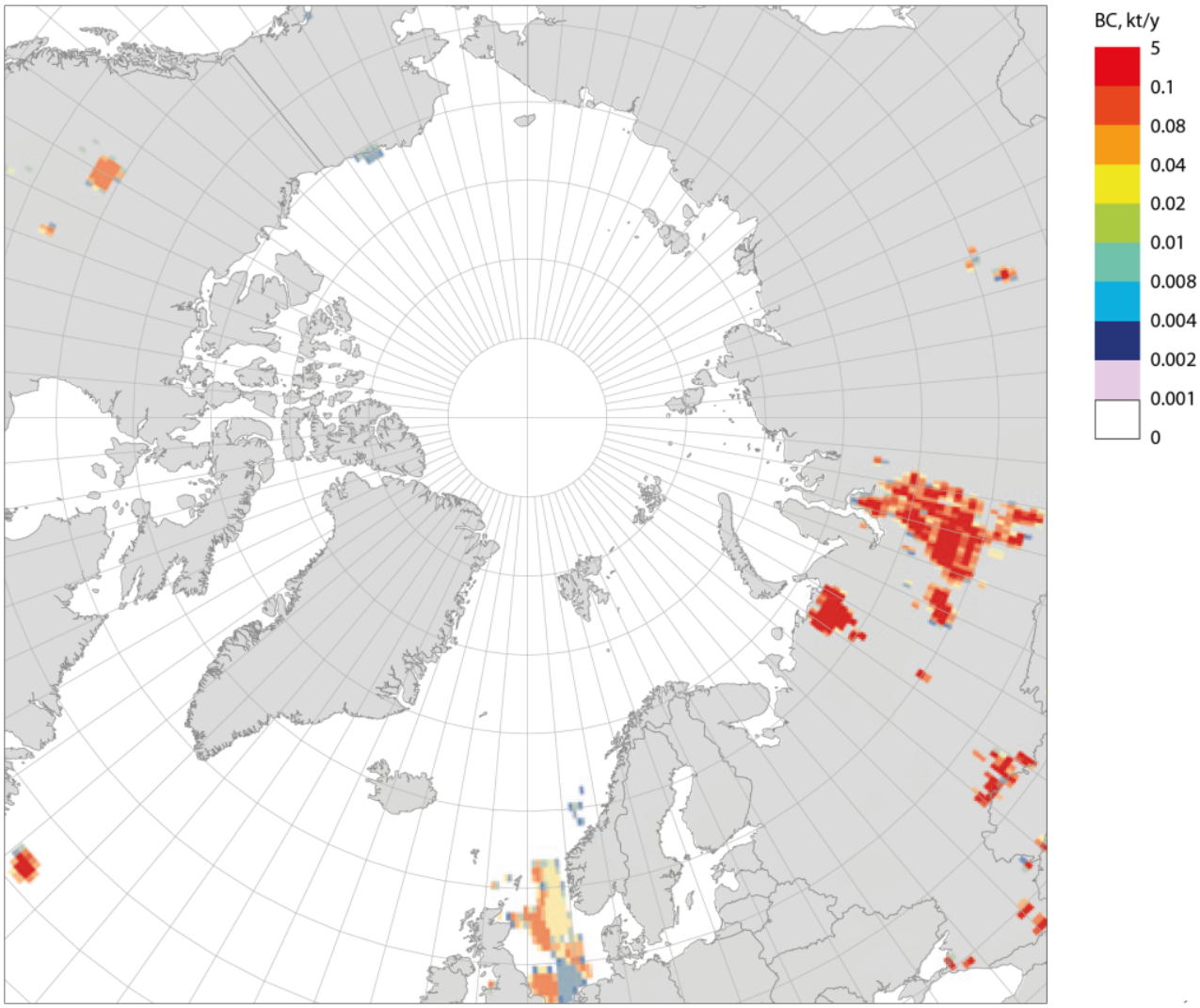


Blue shading: indicates altitudes where BC is expected to cool the Arctic surface.

Red shading: altitudes where BC is expected to warm the Arctic surface.

AMAP BC&O_3 report, 2015

One example: BC emissions from flaring oil/gas

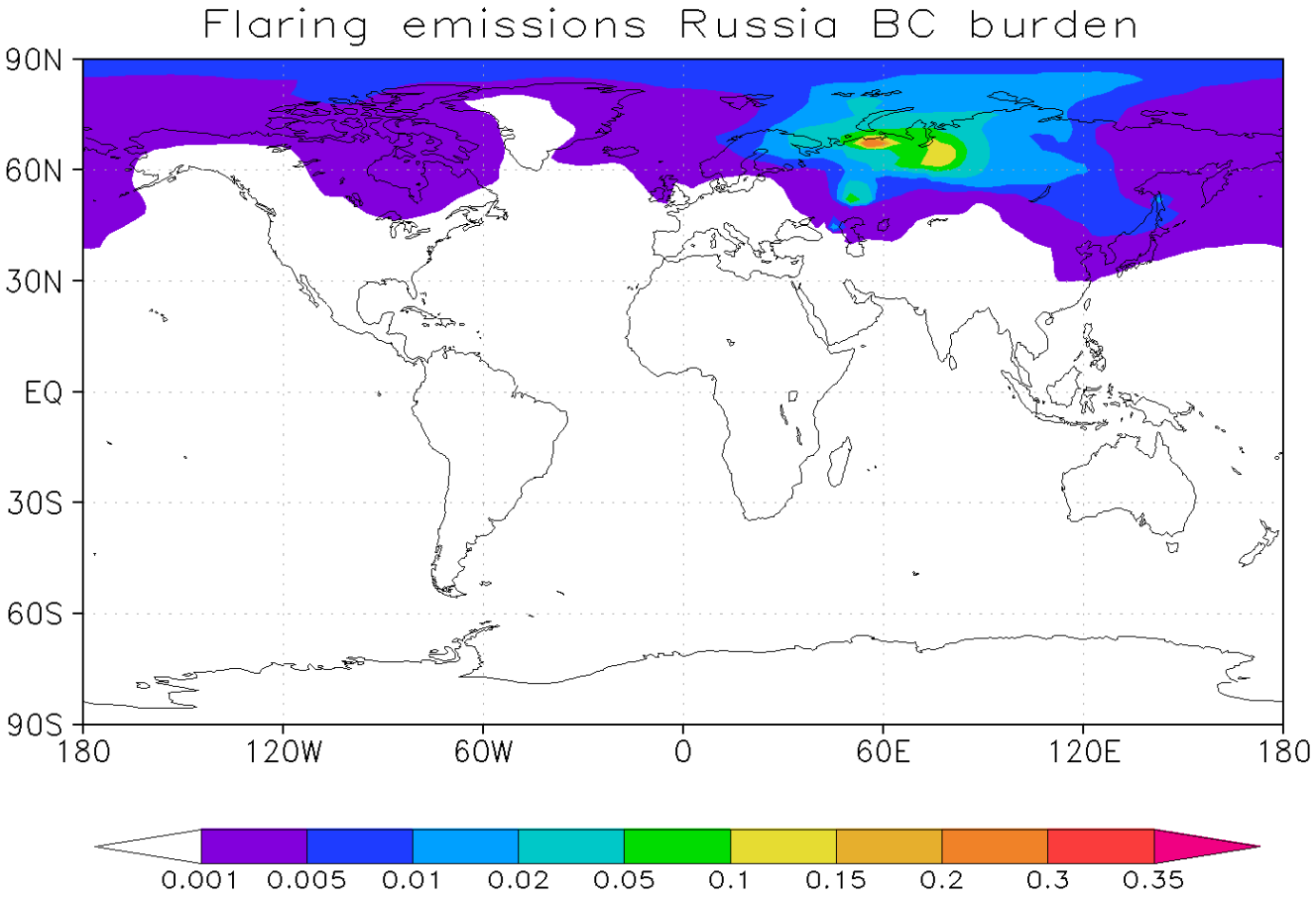


3% of global BC emiss, 33% >60°N, 66% >66°N

AMAP BC&O_3 report, 2015

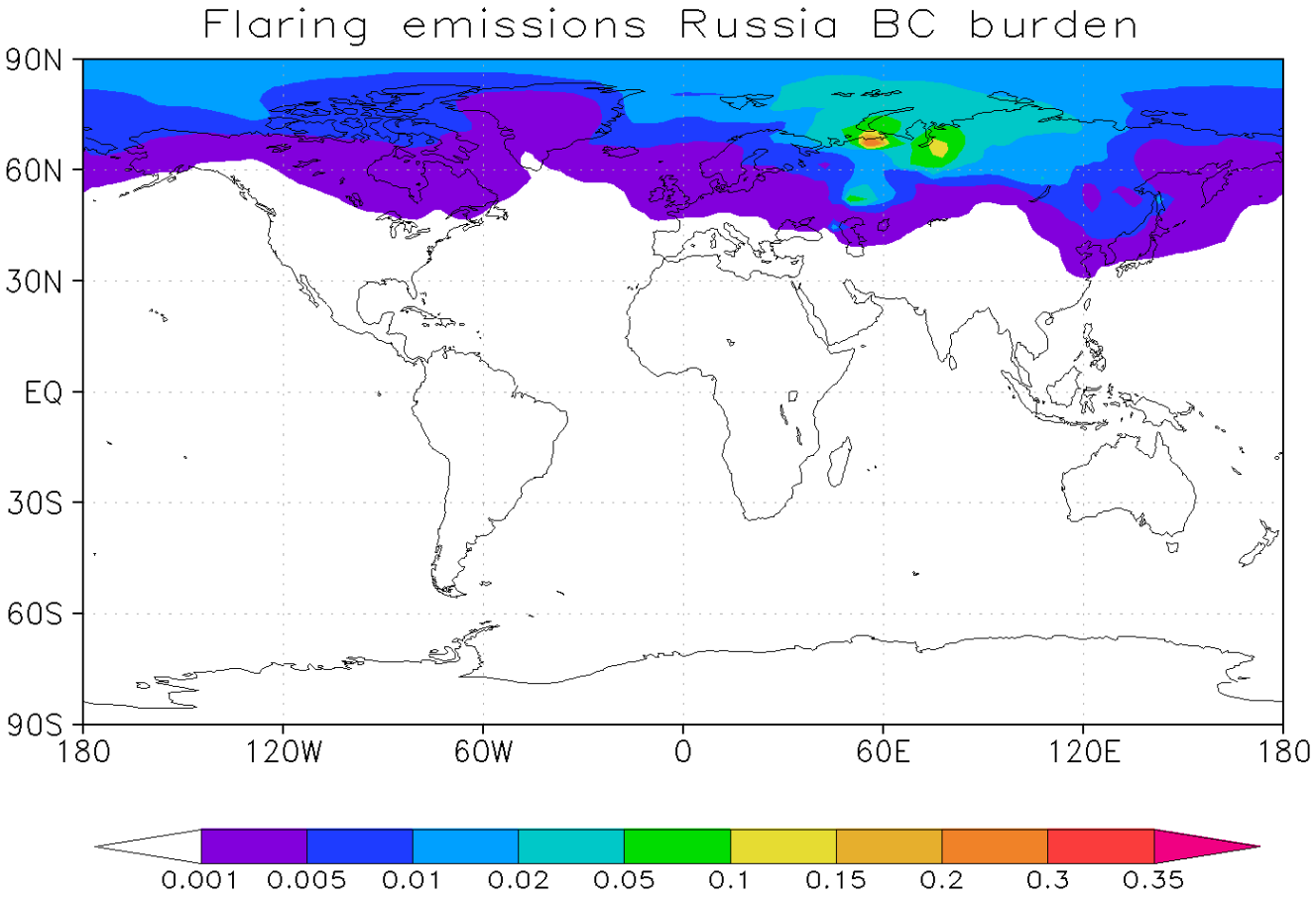
One example: BC emissions from flaring in Russia

JAN



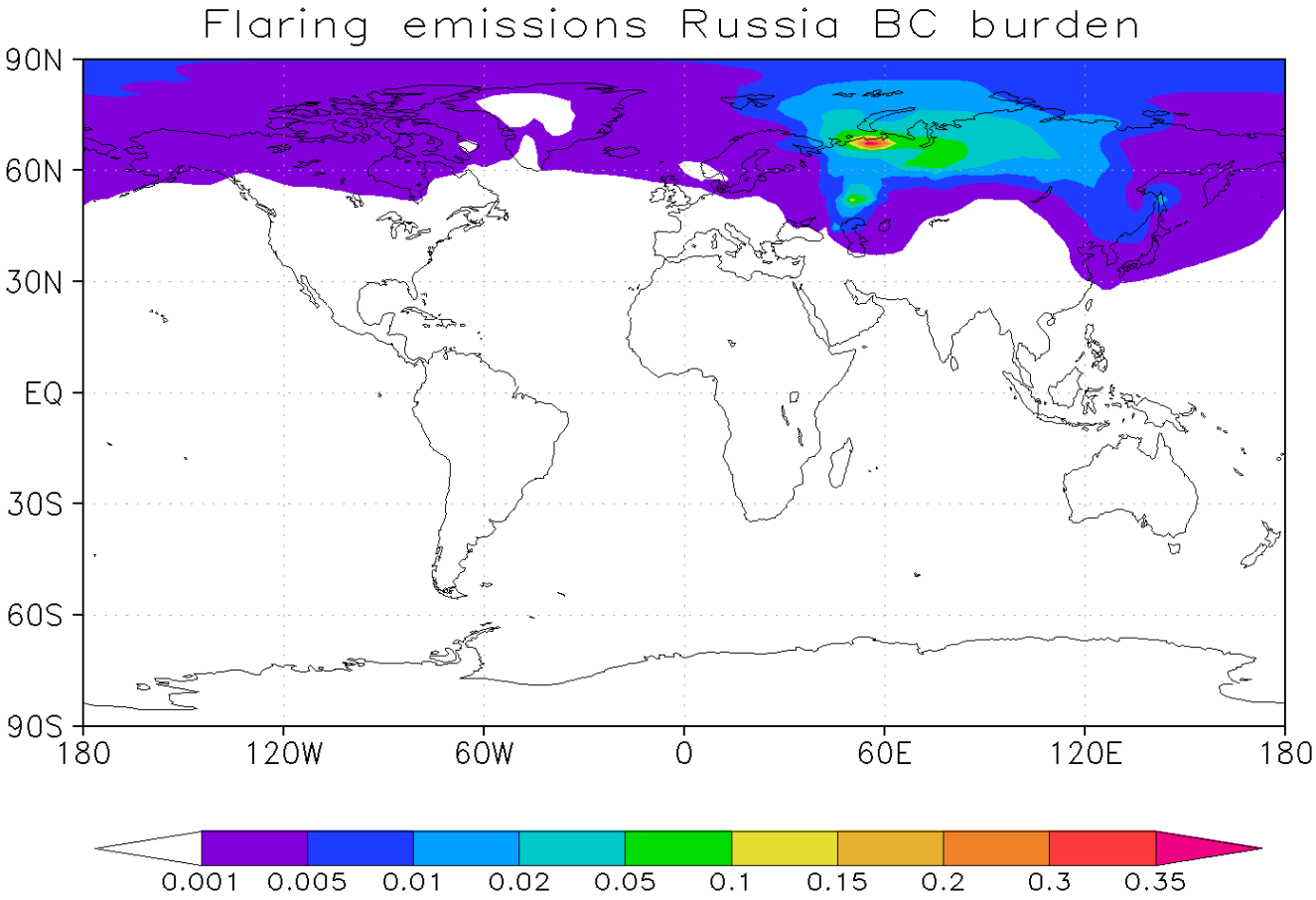
One example: BC emissions from flaring in Russia

FEB



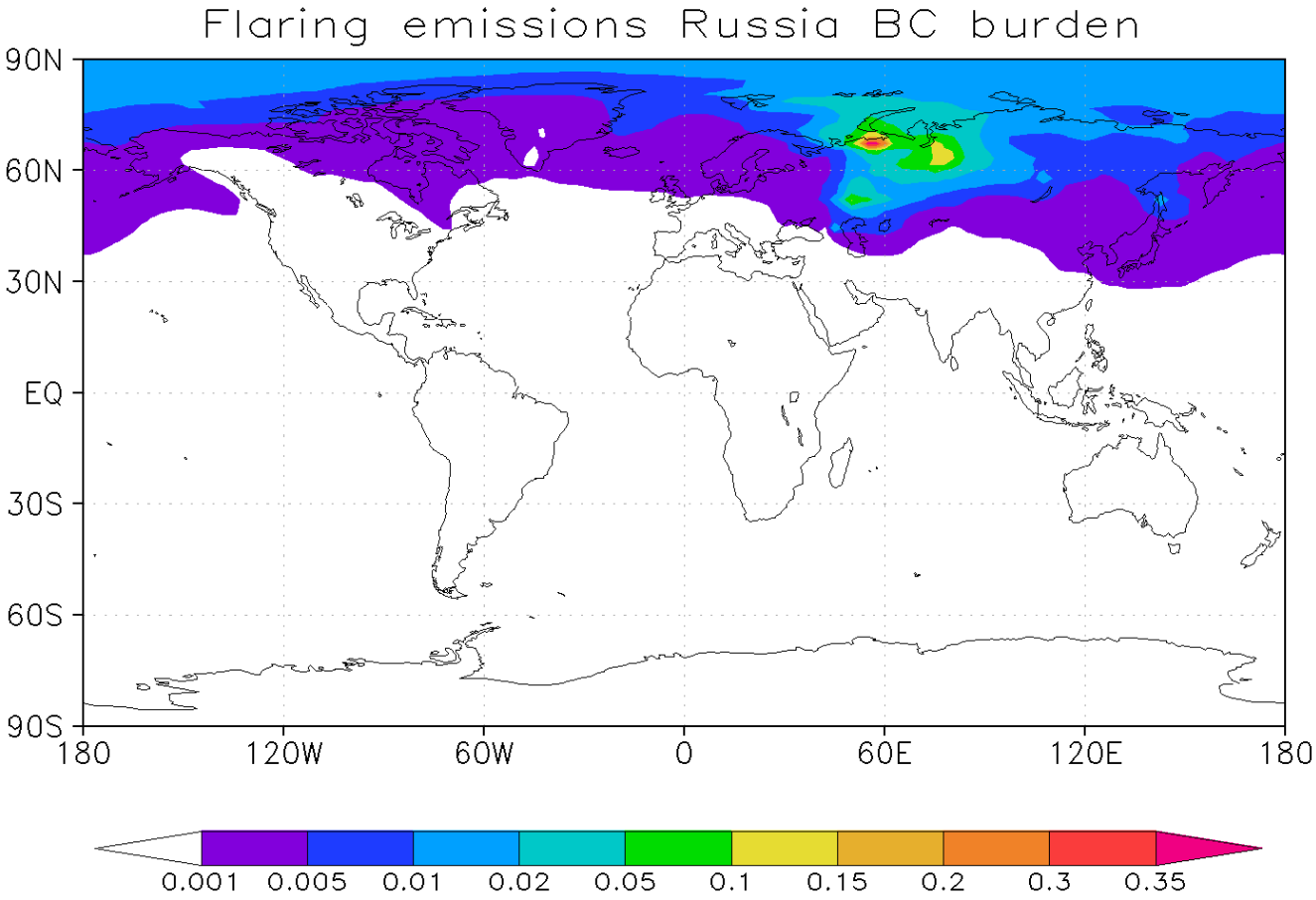
One example: BC emissions from flaring in Russia

MAR



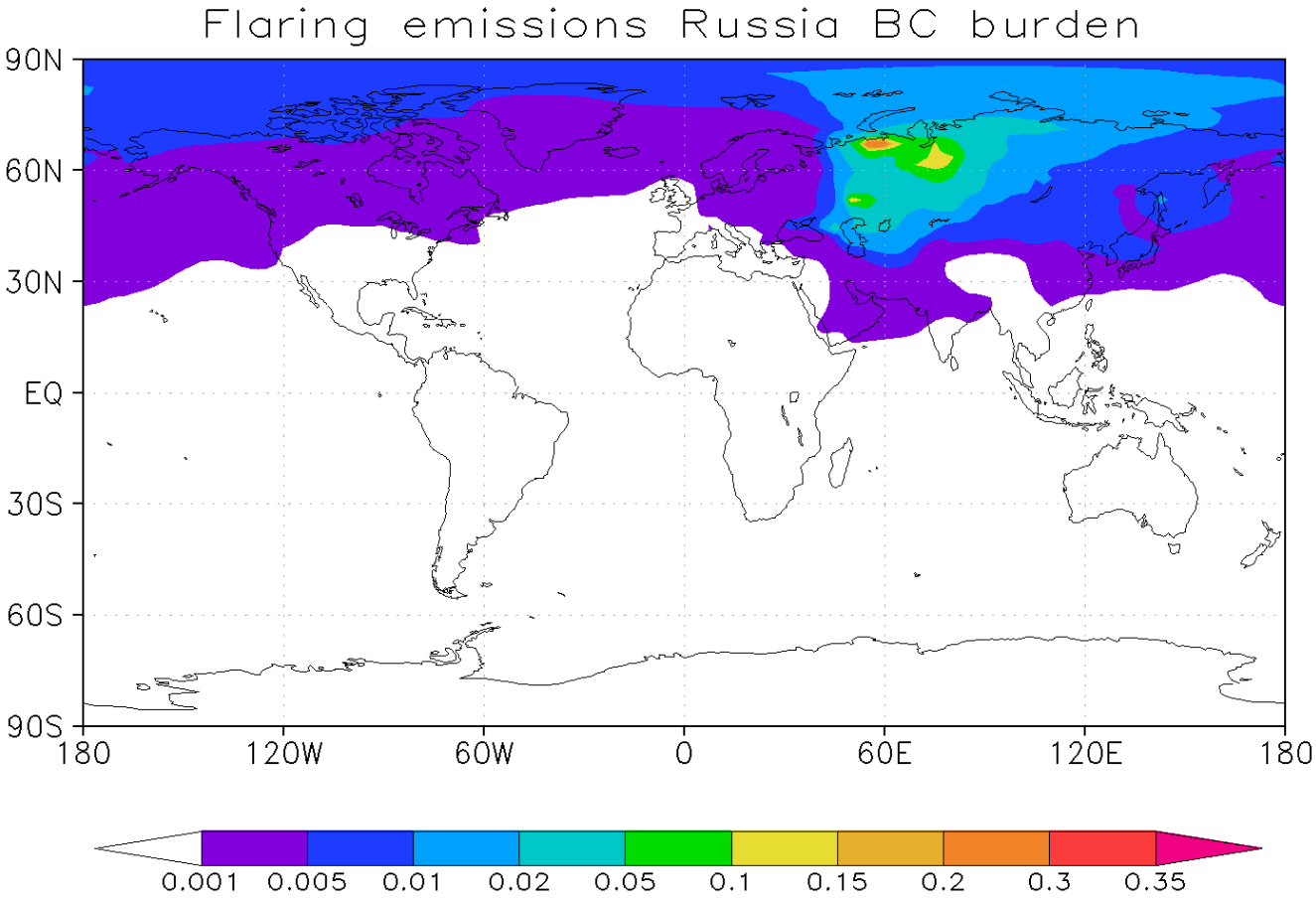
One example: BC emissions from flaring in Russia

APR



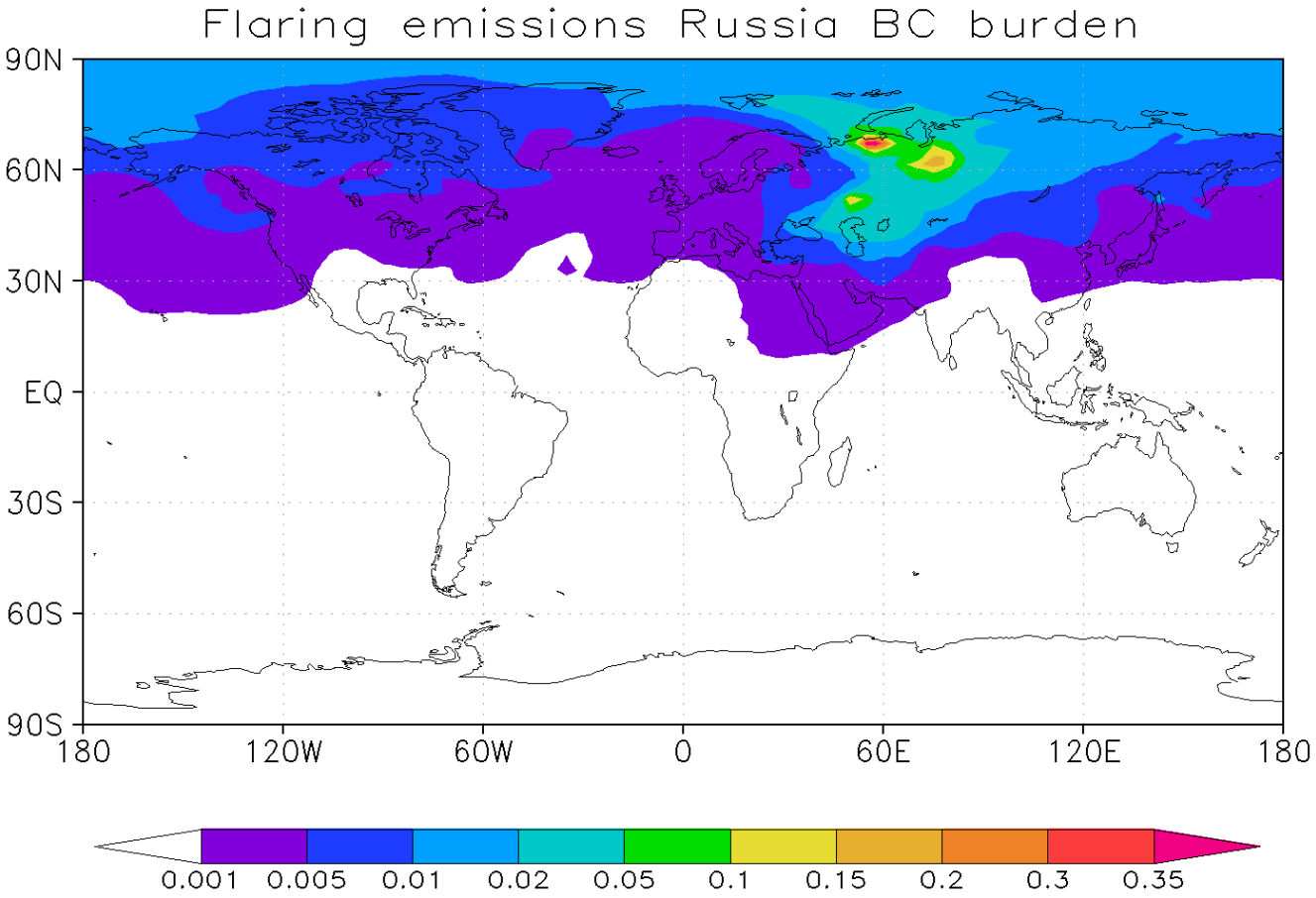
One example: BC emissions from flaring in Russia

MAY



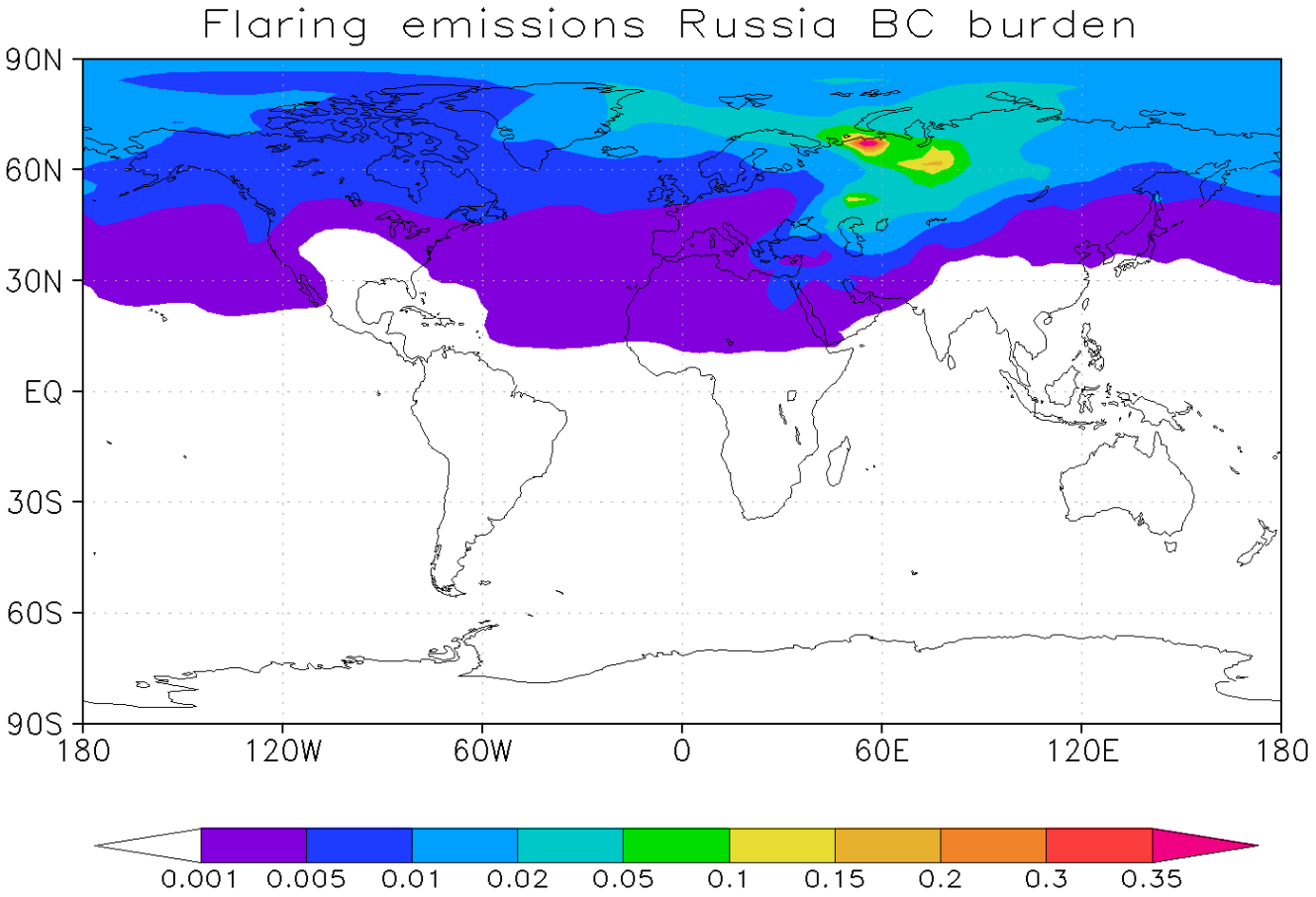
One example: BC emissions from flaring in Russia

JUN



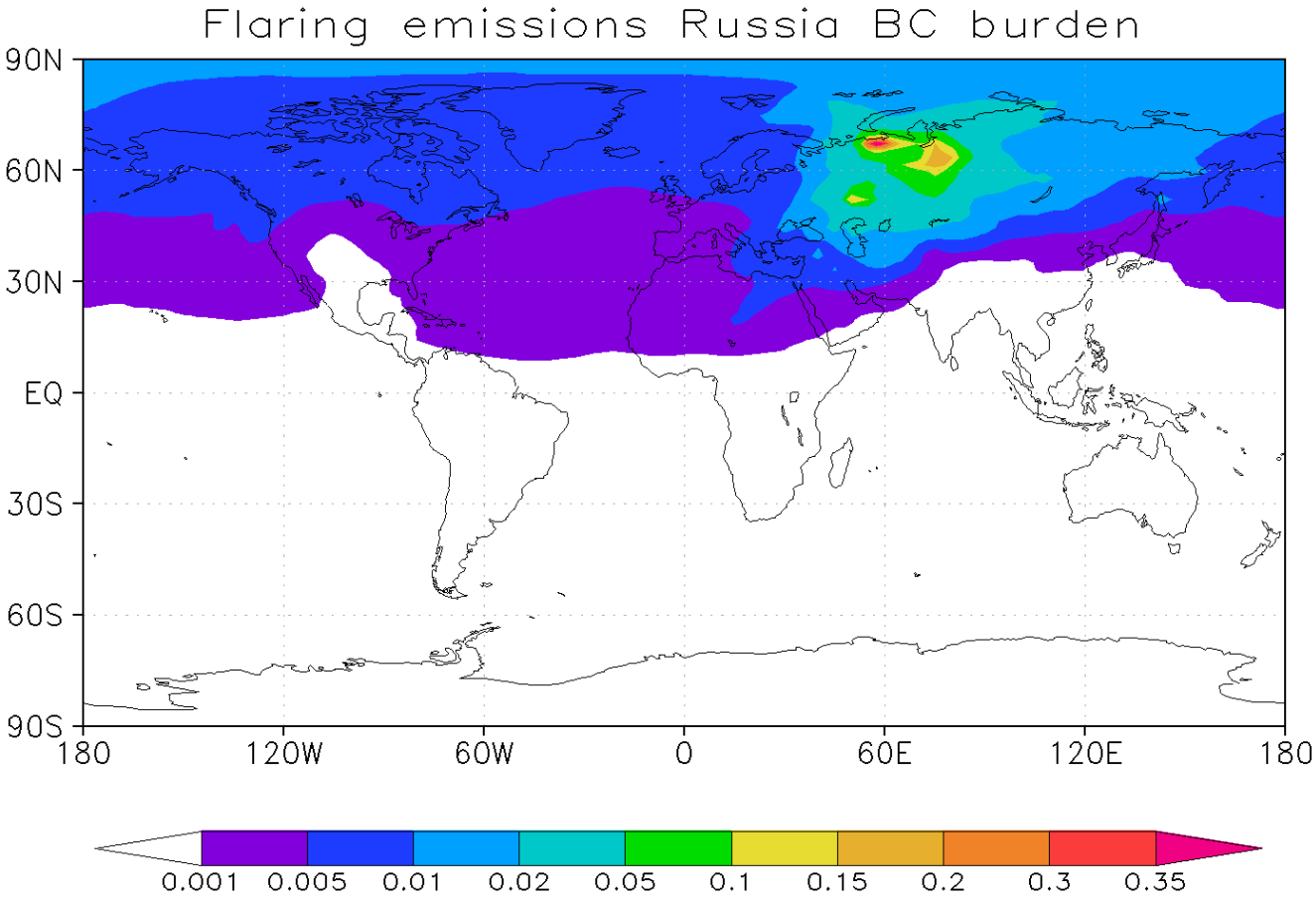
One example: BC emissions from flaring in Russia

JUL



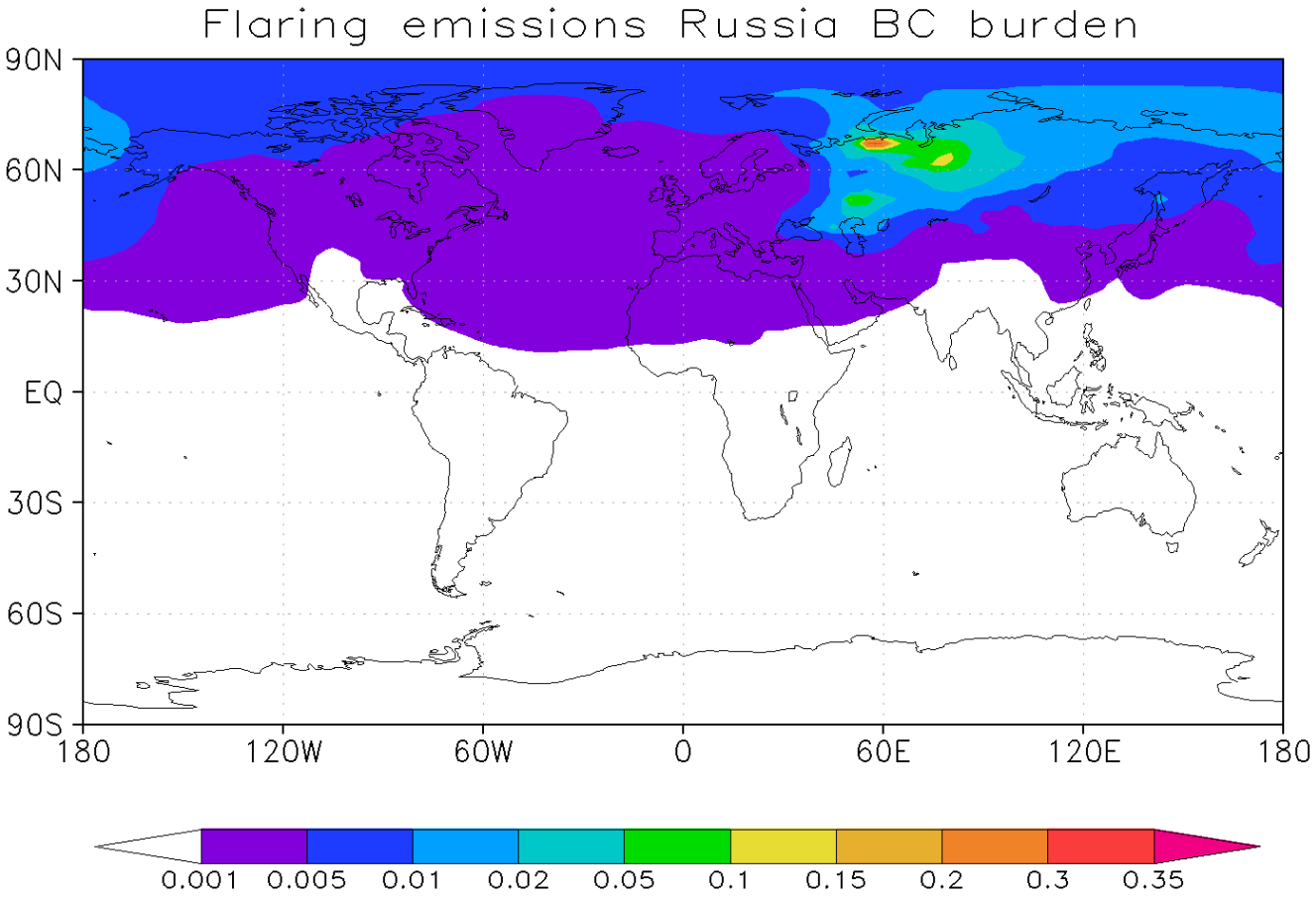
One example: BC emissions from flaring in Russia

AUG



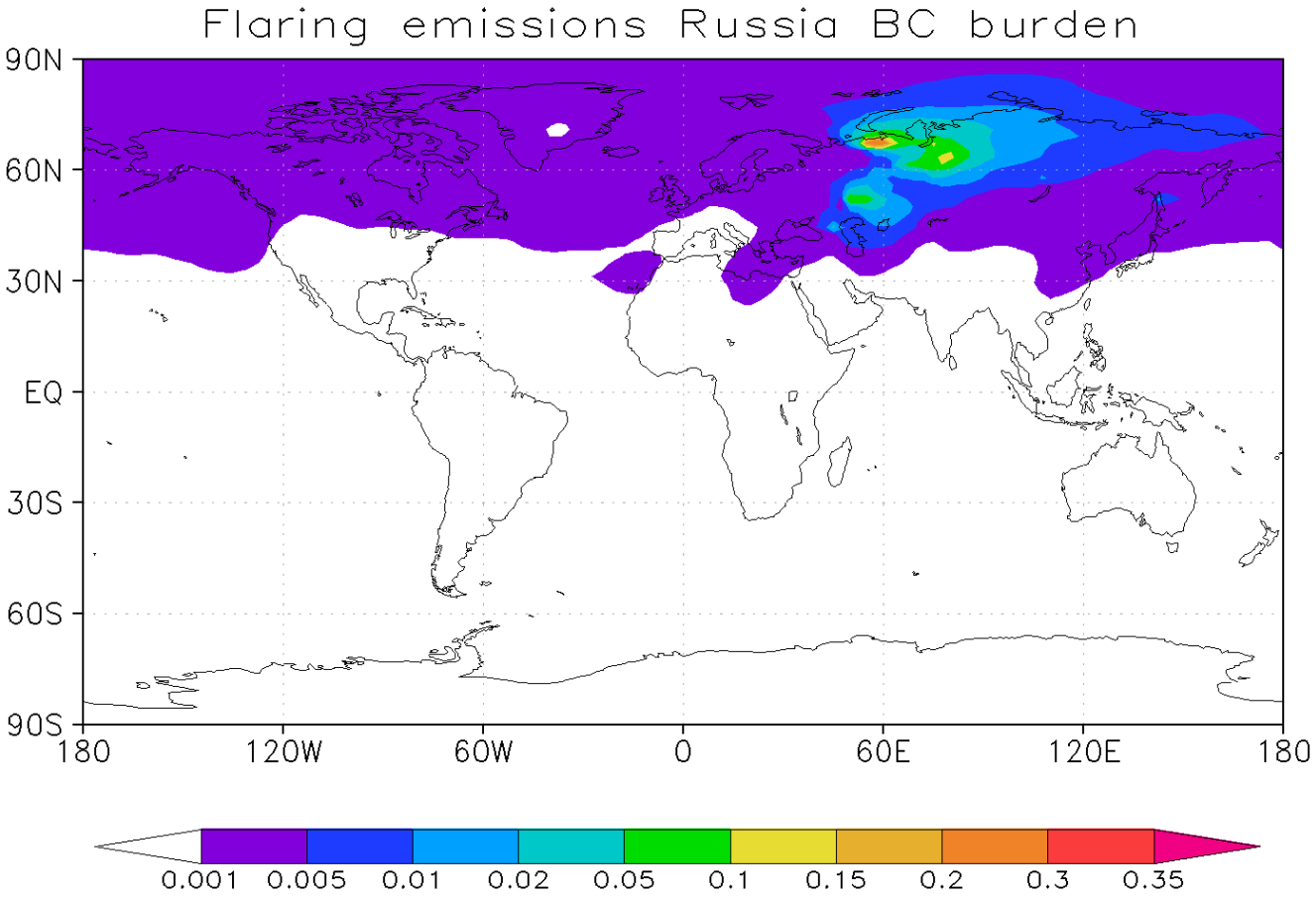
One example: BC emissions from flaring in Russia

SEP



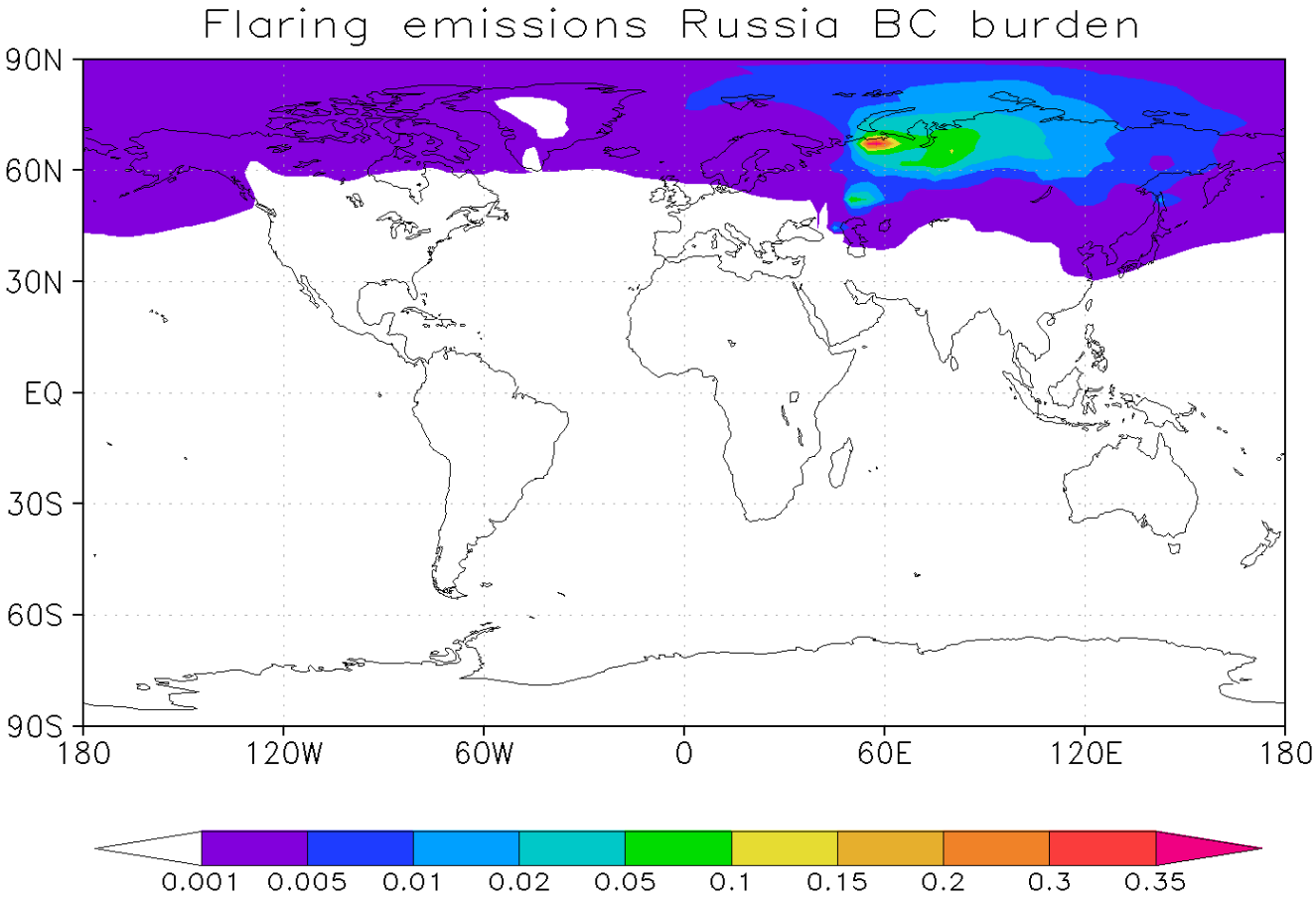
One example: BC emissions from flaring in Russia

OCT



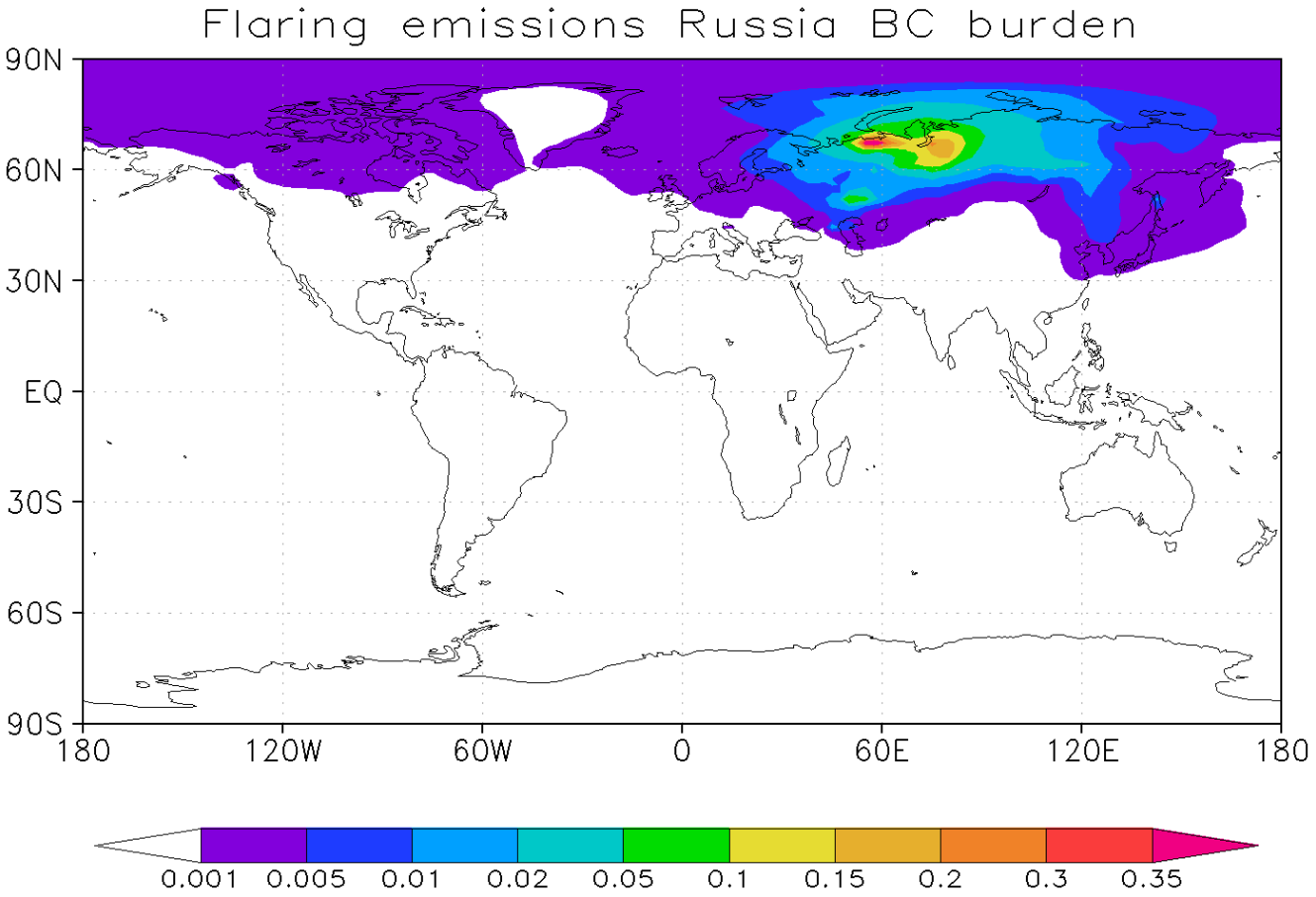
One example: BC emissions from flaring in Russia

NOV



One example: BC emissions from flaring in Russia

DEC



Emission regions

Canada

United States

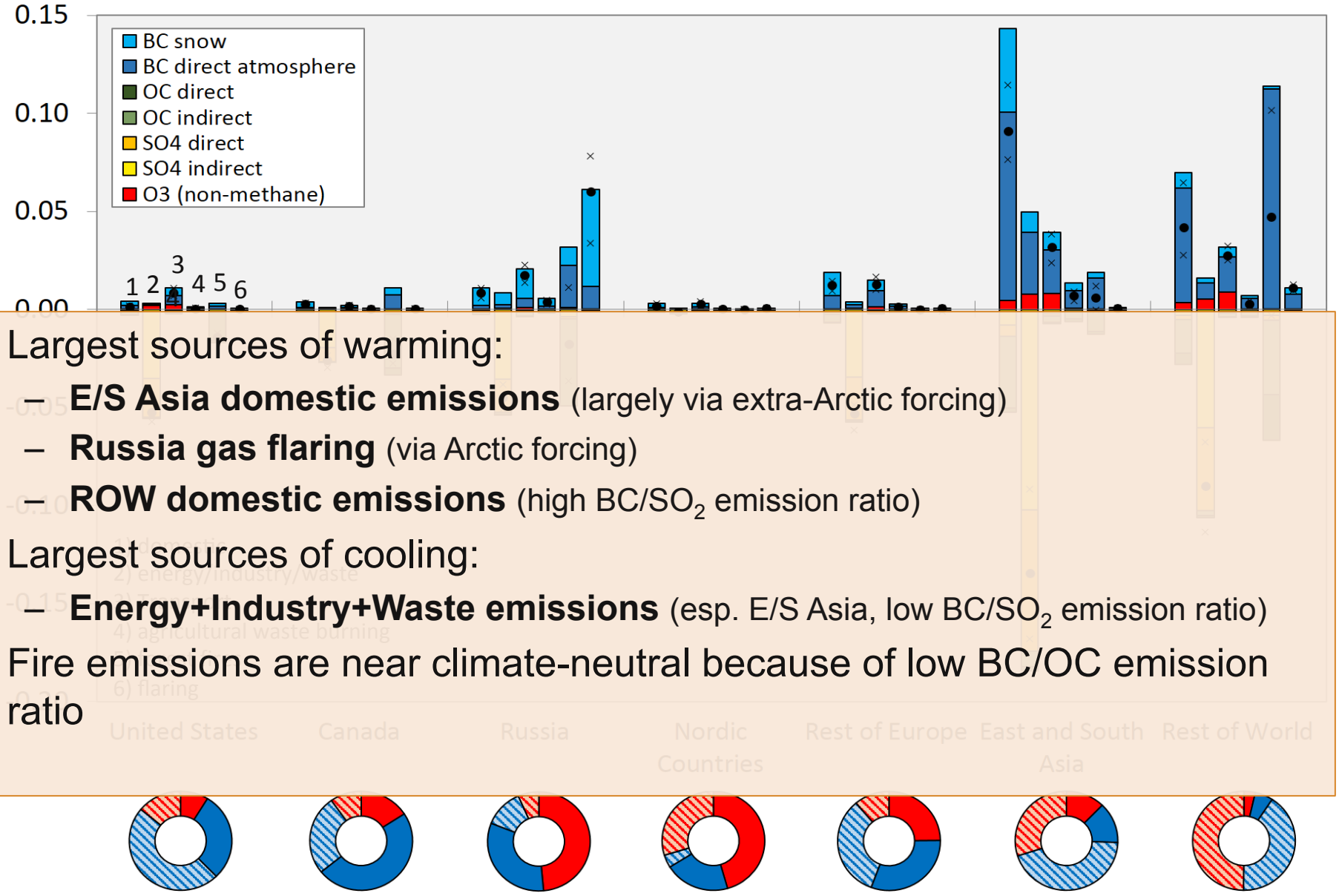
Nordic Countries

Russia

South East Asia

Non-Arctic Europe

Arctic surface temperature change

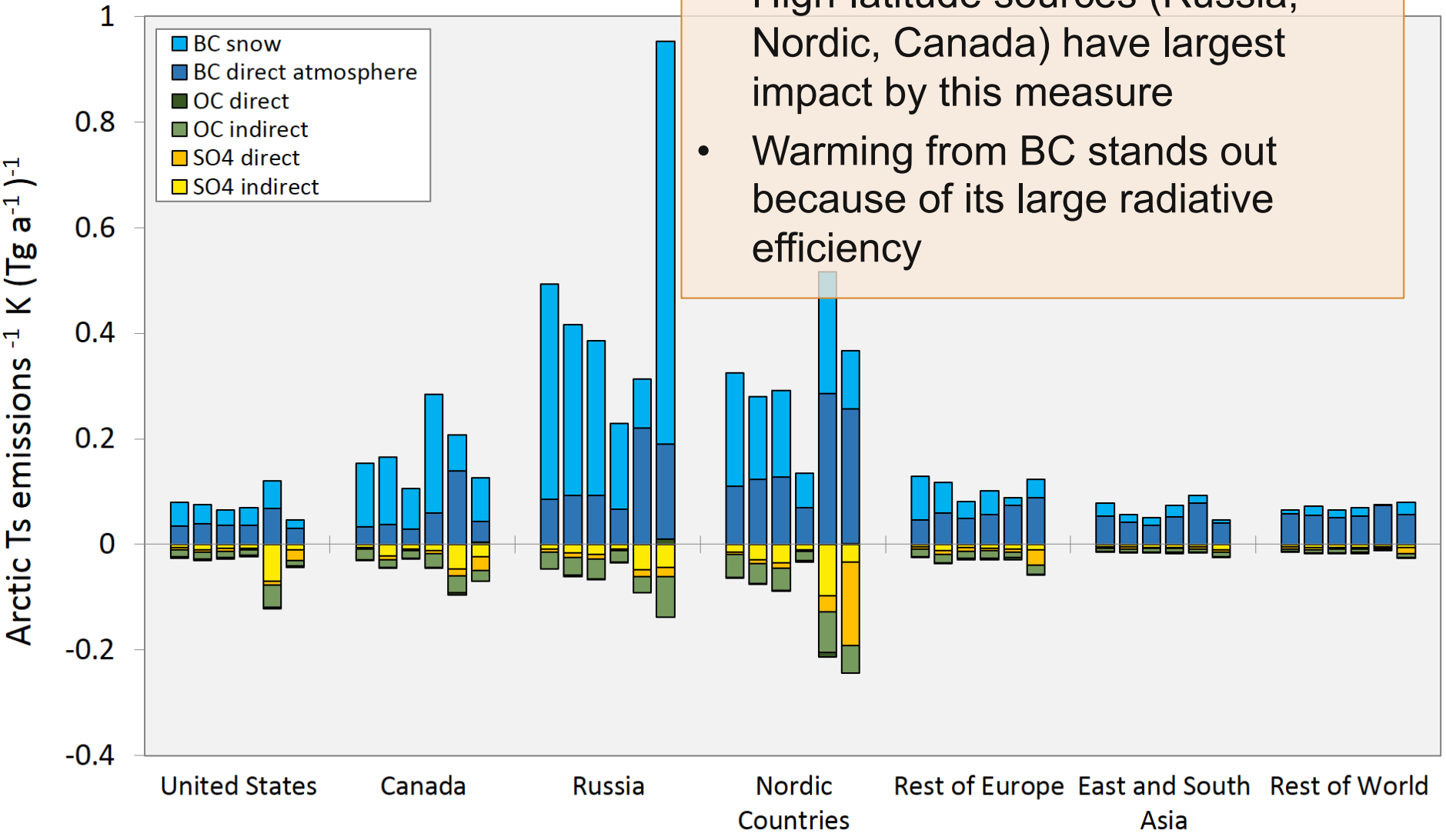


- Largest sources of warming:
  - **E/S Asia domestic emissions** (largely via extra-Arctic forcing)
  - **Russia gas flaring** (via Arctic forcing)
  - **ROW domestic emissions** (high BC/SO_2 emission ratio)
- Largest sources of cooling:
  - **Energy+Industry+Waste emissions** (esp. E/S Asia, low BC/SO_2 emission ratio)
- Fire emissions are near climate-neutral because of low BC/OC emission ratio

Sand et al., NCC, 2015

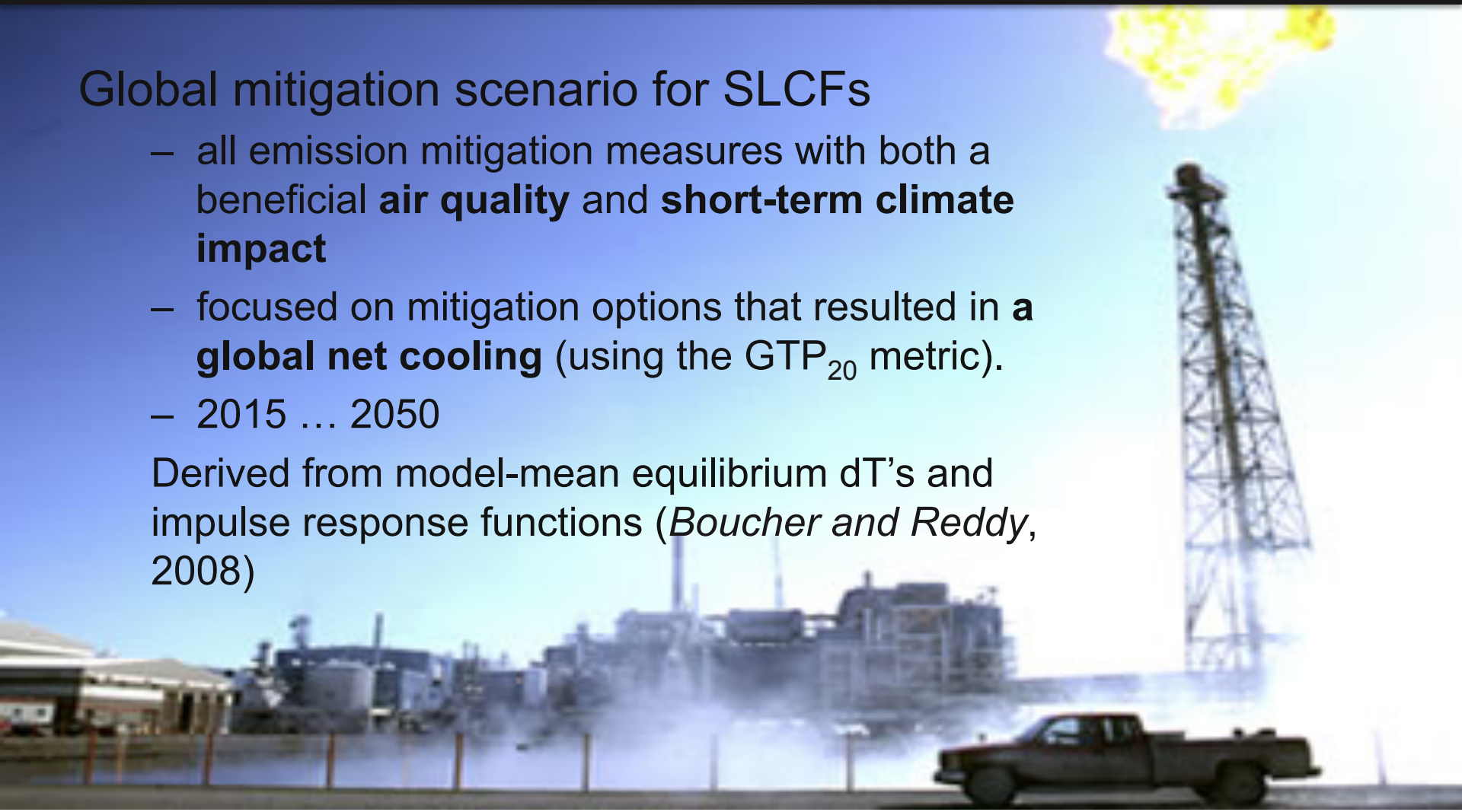
‘Bang for the buck’

- High-latitude sources (Russia, Nordic, Canada) have largest impact by this measure
- Warming from BC stands out because of its large radiative efficiency



Sand et al., NCC, 2015

Mitigation potential

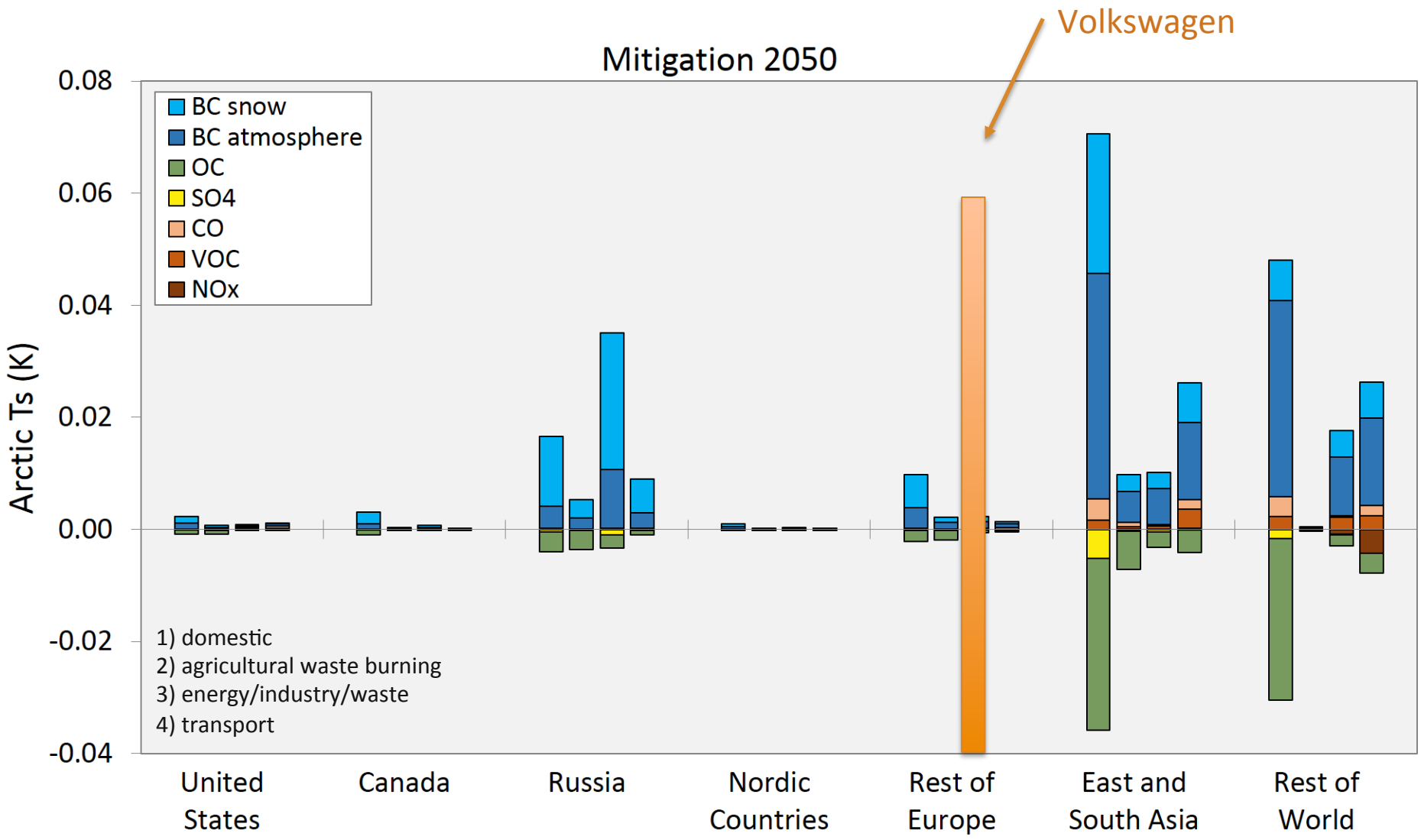


Global mitigation scenario for SLCFs

- all emission mitigation measures with both a beneficial **air quality** and **short-term climate impact**
- focused on mitigation options that resulted in **a global net cooling** (using the GTP_{20} metric).
- 2015 … 2050

Derived from model-mean equilibrium dT's and impulse response functions (*Boucher and Reddy*, 2008)

Mitigation potential Arctic surface temperatures



Sand et al., NCC, 2015